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MUSHROOMS

FUNGICIDE BENEFITS ASSESSMENT

National Agricultural Pesticide Impact Assessment Program (NAPIAP)

FUNGICIDE BENEFITS ASSESSMENT

MUSHROOMS

January, 1991

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This Report Represents a Portion of the USDA/States
National Agricultural Pesticide Impact Assessment Program (NAPIAP)
Fungicide Assessment Project

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PREFACE

Plant diseases affect all the major food crops world-wide and must be controlled to prevent significant production losses and maintain food quality for animals and humans. In addition, fungicides are a necessary factor in maintaining the availability of fiber and landscape improvements ranging from forest management to enhancements through the use of ornamentals. Agricultural fungicides are a significant component in effective disease control and are critical to plant health management systems. Fungicides provide benefits to producers as well as consumers and to local as well as national economies. Farmers benefit from the prevention of yield losses, improved crop quality, enhanced market opportunities, facilitation of farmwork and harvest. Consumers also benefit from an ample, varied, safe, healthy and inexpensive food supply that is available throughout the year.

This is one of 11 separate reports that assessed the beneficial aspects of fungicide use in U.S. agriculture. The 11 reports, all using a commodity approach in evaluating fungicide use, comprise the Fungicide Benefits Assessment. This assessment represents one part of the USDA/States National Agricultural Pesticide Impact Assessment Program's Fungicide Assessment Project. The two other parts deal with (a.) a treatise examining the health and environmental factors associated with the agricultural use of fungicides, and (b.) an assessment of the status as well as the management strategies for fungal resistance to fungicides in the U.S.

The 11 Fungicide Benefits Assessment reports were prepared by a team of scientists (team leaders). The team leaders and the listing of their reports (by commodity) in the Fungicide Benefits Assessment are as follows:

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SUMMARY

1. Loss of zineb for mushroom disease control has been temporarily mitigated by a Section 18 for chlorothalonil.

2. EPA is considering if chlorothalonil satisfies the registration standard. Loss of chlorothalonil and zineb equals significant crop loss for mushroom farmers.

3. Pennsylvania mushroom farmers need 100% of average production to survive financially.

4. The diseases controlled by zineb or chlorothalonil, left uncontrolled, would result in crop losses of 10% or more.

5. Loss of the mushroom industry in Pennsylvania would cost the State $216.4 million and 2178 man-years of work.

INTRODUCTION

Geographic distribution: Commercial mushroom farming occurs in 24 states with the major production in Pennsylvania (44%) and California (4%). Five (5) percent of the crop consists of specialty mushrooms, and the remaining poundage is the button mushroom (*Agaricus bisporus*). Among the specialty mushrooms are *Lentinus edoides* and *Pleurotus* sp. (Shiitake and Oyster mushrooms, respectively).

1. Units planted: 132,271,000 sq. ft. (3036 A; 1229 ha.)
2. Units harvested: same as #1
3. Chemical
   - A. Chlorothalonil
     - a. Formulation: Bravo 500 (EPA Reg No. 50534-8)
     - b. Applications: 0.26 lb. ai per 1000 sq. ft. after casing
0.13 lb ai per 1000 sq. ft. at pinning prior to each break
     - c. Apply in irrigation water,ca. 1 gal per 32 sq. ft.
     - d. Unit to be treated: same as #1.
     - e. Diseases subject to control: Verticillium brown spot and dry bubble. All crops are subject to this disease, and chlorothalonil is used as a preventative treatment.
       - 1) Disease severity and loss: The endemic level of this disease is between 5 and 10% of total yield. Occasionally, total crop failure occurs and with greater frequency, crop loss is 4 to 6 times the endemic level.
     - f. Normal management practice: Growing rooms at mushroom farms are used repeatedly during a calendar year for new crops. Between crop sanitation consists of steam pasteurization of the room and its contents (spent mushroom compost with a peat moss top dressing), a thorough rinsing with water after the compost is removed, and an application of a phenol-based sanitizing agent to the nonproducing surfaces (walls, floors, etc.). Salt is used on floors and outside roadways to reduce dust, a carrier of pathogens. Picking baskets and basket hangers are washed with water before they re-enter a room. Pickers wash their hands before work and wear clean clothes to avoid carrying the pathogen into a growing room. Infected mushrooms are removed by specially trained crews whose job is to remove infected mushrooms (i.e., a trashing crew).
     - g. The only EBDC registered for use on mushrooms was zineb. Mancozeb (Dithane M45) is a much more effective dithiocarbamate fungicide than zineb for disease control. Mancozeb is the fungicide of choice when an EBDC is registered for use on mushrooms. Aside from the EBDC's,

thiabendazole (Mertect 340F) is used occasionally. Benlate, 50% benomyl, is used by some farmers as a drench similar to thiabendazole. The effectiveness of Benlate is limited considering that 90% of all <u>Verticillium</u> <u>fungicola</u> isolates are resistant to this fungicide.

4. Federal/State recommendations: Use chlorothalonil and thiabendazole as described on their labels. Institute and maintain a sound sanitation program between crops. Always wash picking baskets and picking equipment before allowing them in a growing room. Insure that pickers arrive in clean clothing, or provide them clean clothing, and insist that hands are washed in soap and water before picking.

5. Disease management
   A. Management without chemical pesticides: see #4. There are no Verticillium resistant mushroom strains (cultivars), so this is not an option. Biotechnologists have disease resistance as a high order priority, but the time for development is unknown.
   B. Management without adequate controls: sanitation, hygiene, restricting or removing infected mushrooms.

BACKGROUND

Mushrooms are fungi, and their nutritional characteristics--high in fibre and potassium, zero cholesterol, low sodium, low calorie--make them very attractive to those who are concerned about the wholesomeness of their diets. Per capita consumption of mushrooms has risen dramatically in the past 20 years, as mushrooms have moved from luxury-class condiment to a vegetable for ordinary people. Specifically, per capita consumption of mushrooms in 1988 was 3.56 lbs per person per year (Kazemi, 1989).

A report concerning consumer attitudes reports 60% of the population do not include mushrooms in their diets (Fields and Handley, 1989), so the per capita consumption figures should be adjusted upward considering that only 40% of the population eats mushrooms.

Farming mushrooms is very intensive agricultural production. Capital and operating expenses, about $23,000/crop of 8000 sq. ft., is needed at least 4 times each year because the cropping cycle has been lowered to between 12 and 14 weeks, and the growth rooms remain empty for only 1 or 2 days between crops. Since 1983, the number of mushroom farmers has declined by 40% yet total U.S. production increased 26% by 1989 with 82% of the crop being sold as fresh mushrooms. During this same period, average production (lbs/sq.ft.) increased almost 30% and the price to farmers increased less than 5%, with price per pound decreases for 3 of the 7 years (Anon, 1989). Although total crop value increased $176.6 million from $490.8 to $667.4 million for 172.6 million lbs. v. 216.4 million lbs. between 1983-1989, this was not sufficient to stem the tide of farm closures due to bankruptcies and self-determined farm closures (Baillie, 1987).

Mushrooms are highly perishable and farmers must sell them within hours of harvest. Thereafter, mushrooms must be moved through the channels of distribution so that the end user receives them within 24 to 48 hrs. Rapid post-harvest deterioration of quality categorizes mushrooms in the perishability class of fresh fish; CA storage is not an option for mushrooms, nor is drying. Freshly harvested mushrooms must move to retail, wholesale or processing outlets quickly or face the calamity of no one wishing to buy quality-deteriorated mushrooms. Vacuum cooling and ice bank cooling rapidly lowers the internal temperatures of mushrooms, and transport via refrigerated trucks allows these temperatures to be maintained. Quality deterioration is slowed by removing latent heat from harvested mushrooms and assuring that a storage temperature of 3^0 C is maintained.

Mushrooms are grown in 24 states with Pennsylvania and California growing the highest percentage of the national total, 44% and 4% respectively. Most of the mushrooms are traditional "buttons" or "champignons" while 5% of the total crops in 1989 consisted of oyster and shiitake mushrooms plus a smattering of other species (Anon, 1989).

There are few mushroom farming enterprise budgets published that partition the costs of pest management from other costs (Owens, et. al. 1982; Wuest, 1983). Duffy (1983) reported pest management costs for Pennsylvania farmers are between $0.09 and $0.17 per sq. ft. per crop. His research also reported the value of post-crop steam pasteurization; the amount of time steam was injected into growing rooms was positively correlated with mushroom yield. Agricultural scientists had long recommended this practice since many mushroom pathogens are harbored in the wood of beds and trays, as well as being lodged in the crevices of concrete blocks, the most common interior surface of farms. Sanitation, hygiene and exclusion remain the primary deterrents to insect and disease crop pests of mushrooms (Wuest, 1990a; Rinker & Wuest, 1987b). Yet, there are diseases which are endemic to the crop, and this has not changed much since 1951 when the use of EBDC's was recommended (Fekete, 1967; Gandy, 1972; Wuest et al. 1987; Yoder et al., 1951). Forer et al. (1974) reported on the occurrence of mushroom diseases during a 12-month survey of Pennsylvania farms, and the relative severity of some endemic diseases. Spadafora, et al. (1989) reviews in greater detail some factors which may affect the occurrence of Verticillium disease. He concluded that Fall is when the Verticillium disease is most prevalent although it is significant at other times of the year (Rinker and Wuest, 1987a).

Wuest et al. (1987) reviewed the major diseases and fungal pests of the mushroom. He reported that farmers rank Verticillium as the single most important disease of their crops. Rinker and Wuest (1987b) had reported a negative correlation between Verticillium incidence and crop yield. North (1987) demonstrated that Verticillium can also be a post-harvest, quality deteriorating pathogen. Davenport and Wuest (1989) validated the concerns of North by conducting an extensive survey of retail mushrooms and found *Verticillium fungicola* as the most frequently isolated fungus from symptomatic and symptomless mushrooms. These reports plus those of others confirm that the disease caused by *V. fungicola* is a threat to crop yield and post harvest quality. Both aspects of this disease underscore the level of concern voiced by mushroom farmers (Wuest et al., 1987).

Verticillium is not the only disease of the mushroom crop as there are other fungal diseases--cobweb mildew, trichoderma mildew, wet bubble, bacterial diseases--mummy and blotch, a viral disease--La France, nematode and protozoan diseases, Wuest 1987. None of these diseases are endemic but rather are sporadic in appearance. Fortunately, the benzimidazole fungicides, benomyl and thiabendazole, are reasonably effective for most of the sporadically occurring fungal disease. Mummy is a systemic bacterial infection with no known control. Indexing mushroom spawn minimizes the frequency of La France epidemics, and good crop hygiene is somewhat effective for managing the other maladies. The endemic nature of Verticillium and its ability to reduce both yield and quality elevate this disease to a major threat to the survival of mushroom farms (Fekete 1967; Wuest, 1990b).

This report provides some data regarding disease occurrence with and without the use of zinc ethylene bis-dithocarbamate (Zineb) to control Verticillium disease. The current costs of mushroom farming are reviewed and integrated with the impact Verticillium disease can have as farmers strive for profitable mushroom farming in 1990.

1. Zineb and Verticillium Disease Control on Mushrooms

The USDA/State/EPA Assessment Team drafted a well conceived, thorough report in 1978 containing an in-depth consideration of zineb and mushrooms. An excerpt of this report constitutes Appendix I, and it is intended to provide investigators with substantiative information to consider in assessing this matter.

Considering that no company was committed to the reregistration standard for zineb and mushrooms before December, 1989, a special exemption, Section 18 FIFRA for chlorothalonil, was submitted to the Pennsylvania Secretary of Agriculture in June, 1989. The reasons for this exemption and the potential benefits to farms were reviewed in full in this petition. Relevant portions of this petition, including exhibits, are included as Appendix II. From a farmer's perspective, a yield reduction of 10% because of Verticillium disease was/is adequate to transform a profitable business into a bankrupt business.

2. Alternatives to Zineb for Verticillium Control

The section 18 petition for chlorothalonil, Appendix II, reflects an option for zineb to control Verticillium. Appendix III is an article reflecting the disease control possibilities of mancozeb for Verticillium, but it is unlikely this EBDC will be registered.

3. Fungicide Resistance in Mushroom Production

NAPIAP reported on the impact of fungicide resistance by mushroom pathogens-Spring, 1989. The occasion of fungicide resistance to narrow-spectrum mode of action fungicides is reviewed in Appendix IV. Fungicide resistance and its management depends on the availability of one or more broad-spectrum fungicides, as well as the judicious use of selective action fungicides.

4. Significance of Crop Loss on the Financial Viability of Mushroom Farms

The paucity of enterprise budgets for mushroom farmers caused me to survey Pennsylvania mushroom farmers during May, 1990, to ascertain the cost of growing mushrooms.

Table 1. Pounds of mushrooms (per square foot) needed to reach the breakeven point (neither loss nor profit) in Pennsylvania in May, 1990[a].

Mean	5.5 lbs/ft^2
Range	5.1 to 6.4 lbs/ft^2

[a] Data obtained by telephone survey of farmers who grew ca. 60% of the Pennsylvania crop.

Perhaps the first startling revelation about these production figures is that neither the national average, 5.17 lbs/ft^2, nor the Pennsylvania average, 4.90 lbs/ft^2, is adequate to reach the financial breakeven point at mushroom farms. Consequently, one might reasonably expect the exodus of more farmers from the mushroom industry nationwide. These data suggest that any and all factors with a negative impact on crop yield will hasten the failure of mushroom farms. Lack of adequate disease control is one such factor since Verticillium disease results in between 5% and 10% crop loss. One might judge the magnitude of this loss as ordinary in an agricultural context, yet the impact crop losses have on a farm business depends on the margin of profit at each business enterprise.

The matter of mushroom farm sustainability from a financial vantage is very important to those concerned with entry-level jobs that can be learned via on-job-training. Knowing that an average picker harvests 40 lbs. of mushrooms per hour allows for the calculation that shows 7.4 million hours of work were needed to harvest the 1988/89 crop in Pennsylvania (2178 man-years) and nationwide 16.7 million hours (4944 man-years). These hours of work represent 7122 year-round jobs for pickers. An additional 712 jobs at farms support growing and crop harvest. Collection, distribution and sale of mushrooms results in more jobs, as do the services which maintain the infrastructure of the mushroom industry. The financial success of the mushroom industry easily provides year-round employment for 12,000 employees.

Policy strategists may wish to consider the human costs (losses) associated with crop loss and farm closures--employment, tax losses, and consumer losses, when and if mushroom farms fail to be profitable.

CONCLUSIONS AND RECOMMENDATIONS

1. Loss of zineb for mushroom disease control was alarming to mushroom farmers.

2. A Section 18, FIFRA Special Exemption, for chlorothalonil has mitigated the potential for serious crop loss which would have occurred without the availability of a broad spectrum fungicide.

3. Mancozeb is the EBDC of choice, rather than zineb (Wuest, 1990c).

4. Absence of a broad spectrum fungicide will make the management of fungicide tolerant strains of *Verticillium fungicola* impossible.

5. Mushroom farmers need 110% of the national production average to sustain their businesses. Any crop loss will have a significant impact on mushroom farm profitability and survival.

6. A new initiative is needed to bring together and address the needs of farmers, regulators, consumer advocates, and other interested parties.

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APPENDIX I

DRAFT EXCERPT

Assessment of Ethylenebisdithiocarbamate (EBDC)

Fungicide Uses in Agriculture

USDA/State/EPA Assessment Team

Part II. An Analysis of Current EBDC Uses; Their Benefit, the Role of Alternatives, and Impacts to Agriculture from Changes in EBDC Use Patterns

Coordinated by the Office of
Environmental Quality Activities

USDA

September, 1978

MUSHROOMS

Efficacy of Zineb as a Fungicide

Because it is a fungus itself, the mushroom is particularly susceptible to fungal diseases that thrive in the environmental conditions the mushroom depends on. New disease threats arise to meet changes in cultural practices brought about to resist existing threats or to increase productivity. One such crisis rose in the 1940's just prior to the introduction of zineb in 1950.

By the fall of 1947, the situation was becoming alarming. *Dactylium* mildew, *Mycogone*, and *Verticillium* spot were so prevalent that even in the first break (harvest) nearly half the mushrooms were spotted or diseased, and by the end of the third break only an occasional mushroom escaped infection. The only reasonable solution appeared to be the discovery of a fungicide that could be applied to the beds to kill the pathogens without injuring the mushrooms. [1]

The worst of these diseases was, and still is, *Verticillium malthousei* (dry bubble disease), U(2) for which zineb is the only effective defense. Zineb is also effective against other fungal pathogens such as *Dactylium* (mildew), *Mycogone* (wet bubble), and *Trichoderma* (green mold),[(1)] as well as at least one viral infection (Lafrance disease).

Sinden (3) has provided a complete overview of mushroom cultivation and of pathogens and weed-molds affecting the culture. His description of the pathogen *Verticillium malthousei* follows:

> *Verticillium malthousei* Ware causes a serious and widespread disease of the sporophores, perhaps the most destructive, and certainly the most ubiquitous of all pathogens of the mushroom. It is endemic on nearly all farms.... Infection of young mushrooms produces small, deformed, undifferentiated, non-necrotic spheres, called dry bubbles, with a dry surface covered with a dusty gray layer of conidia. Later infections on the surface of the large sporophores develop into localized, brown, depressed, necrotic spots also soon covered with the fine grayish layer of spores...
>
> Intensive production in air-conditioned rooms on trays, where six to seven crops per year are grown, in contrast to three or at most four crops on a shelf-bed farm, necessitates a high relative humidity of 90-95% and a temperature of 59-63^0 F. These are exactly the conditions most conductive to dissemination, inoculation, incubation, and infection of *Verticillium malthousei*. This pathogen, transmitted primarily by living agents such as pickers and parasitic flies, to which the adhesive spores cling, and disseminated secondarily from primary infections by water droplets splashed during watering of the beds..., is difficult to control without resorting to chemical eradicants or protectants...

Since ecological control of Verticillium spot by reduction of the temperature and/or humidity is usually impractical, a selective fungicide is an imperative. One of the earliest fungicides assayed was Bordeaux mixture but it causes injury to the mushroom mycelium so that any mushrooms on the bed at the time of application are made unsalable. In contrast, metal salts of ethylenebisdithiocarbamate specifically target certain fungi since toxicity depends on the presence in a fungus of an enzyme mechanism for reducing the sulfur in the thiocarbamate to H_2S (1). Experience indicates that specificity for Verticillium vs. mushrooms is not total but that the sensitivity difference is sufficient to provide efficient and manageable control.

Some idea of the potential losses without effective control of Verticillium and other fungi can be obtained by comparing production records from early periods with present production. A 1948 reference showed typical mushroom production rates of 1-1/2 lb/sq. ft./filling (4), which is only about half of present rates. (A "filling" is one use of a given bed area.) Much of the increase since then may be attributable to improvements through other pesticides as well as fertilizers and other cultural innovations, so quantitative losses now from a zineb cutoff would be unlikely to exceed 50%. However, qualitative losses would also have to be considered.

Early experiments investigating potential control agents for Verticillium compared Bordeaux mixture with the ferric (Fermate or ferbam) and zinc (Zerlate or ziram) salts of dimethyl dithiocarbamate. It was shown that Bordeaux mixture gave no better control than the checks (1).

Additional experiments showed that both of these dithiocarbamate fungicides provided higher yields as well as high percentages of healthy mushrooms, and that the newer EBDC formula, Parzate (or zineb), was superior to both of them. The data from these tests (shown in Figure 1) indicate the untreated trays yielded 14.7 lbs/tray with 54.8% disease incidence, while the trays treated with Parzate (i.e., zineb) produced 16.6 lb/tray with a 31.1% disease incidence. These results demonstrated a zineb efficacy of 12% more mushrooms with a 23% lower disease incidence. Another experiment in which zineb concentrations were varied showed an average increase of 16% in yield and 20% in mushroom size relative to the check plots (1).

Dusting with zineb, as opposed to spraying, was subsequently established as the preferred mode of application. Table 1 presents data on a comparatively recent series of experiments designed to compare spray dosages and times of applications with dusting. The dust treatment generally yielded slightly lower than the other treatments (including the check) but was consistently superior in controlling disease.

Table II presents some results of more recent tests comparing pathogen control measures. By chance, the Verticillium spot in these three tests was so heavy that without zineb virtually no salable mushrooms would have been harvested. With zineb the spot was brought into tolerable limits with reduction of about 15% in the number of spotted mushrooms in two tests, and of almost 85% in the third test. Yields were increased with zineb by 5% in two of the tests and by 0% in the third.

Table III (which incidentally shows the overwhelming effects of _Verticillium_ spores deliberately added to the mushroom beds at various times during production) indicates in the two checks that the plot dusted with zineb produced 13% more mushrooms and had 18% lower incidence of disease than the uninoculated plot. Since these results are intermediate among the various test results and they are from a well documented and relatively recent test, they will be considered as the expected efficacy from the use of zineb.

Efficacy of Alternatives

There are no presently known alternatives to zineb in mushroom culture. At one time benomyl was regarded as a very promising alternative but tolerance of _Verticillium_ to benomyl developed very rapidly. "Tolerance...often has occurred at commercial mushroom farms in as little as 9 months or less of continued benomyl usage" (6). The rapid establishment of tolerance to benomyl makes the lengthy history of use of zineb truly remarkable and the likelihood of development of a new alternative remote.

Cythion and methoxychlor have been cited as alternatives to zineb, presumably on the basis that controlling fly population will control dissemination of _Verticillium_ spores. Malathion is presently used at many farms in conjunction with zineb as part of the total pest and pathogen control program. As already noted, however, flies are not the only mode of dissemination of Verticillium and insecticides cannot therefore be regarded as effective alternatives to zineb.

Use of ecological controls by such methods as reduction of temperature and humidity are also impractical because these environmental conditions are the very ones that are most crucial to favorable development of the mushroom.

(A list of citations is available from P.J. Wuest, 211 Buckhout Laboratory, University Park, PA 16802.)

Table I

Zineb Spray vs. Dust

Treatment	Dosage	Yield lbs/sq ft.	Bubble/tray[b]	After 35 day %Spot[(b)]
2 lb. Zineb	single	2.17	9.5	4.21
2 lb. Zineb	multiple	2.20	12.8	6.47
8 lb. Zineb	single	2.16	8.5	4.49
8 lb. Zineb	multiple	2.21	7.8	5.98
16 lb. Zineb	single	2.20	9.9	4.94
Check (no zineb)		2.16	27.6	9.06
Zineb dust		2.10	0.6	0.33

[(a)] Treatments lbs/100 gal. applied day after casing for single dosage. Multiple dosages applied day after casing and after normal watering when pins had formed and between breaks. Multiple dosages ranged 7 to 9.

Dust applied 3 times/week

[(b)] Average 6 tests.

Source: Butler County Mushroom Farm, Inc., PA

Table II

Zineb Dust vs. Verticillium

Treatment	lb/sq ft	lb/lb d wt	Bubble/tray	%Spot[a]
Test 1				
Check[b]	2.49	0.58	3/5	18.9
Zineb dust[c]	2.35	0.61	3/5	3.5
Test 2				
Check[b]	2.38	0.54	22/5	33.3
Zineb dust[b]	2.55	0.58	0/5	19.8
Test 3				
Check[b]	2.35	0.56	12/5	88.6
Zineb dust[b]	2.35	0.56	9/5	3.9

[a] Spot count started 35 days after casing

[b] 60 lbs. compost/tray

[c] 55 lbs. compost/tray

Source: Butler County Mushroom Farm, Inc., PA

Table III

Effect of Verticillium malthousei inoculum on mushroom yield, Verticillium bubble and spot incidence.

Treatment[a] (Time inoculated)	Yield (lb/ft)	Verticillium bubbles/5 ft.^{2} tray	%Verticillium spotted mushrooms of total picked
Check - noninoculated[b]	2.49	182	21
Casing	1.09	823	64
7 days	1.13	966	66
14 days	1.00	1021	74
21 days	1.67	518	59
28 days	2.30	283	27
Check - zineb dusted[c]	2.87	12	3

a Each treatment had five trays (5 ft^2 x 6 inches deep) per test, repeated three times for a total of 15 trays per treatment.

b Noninoculated check refers to the check not inoculated with Verticillium spores. The other treatments except the zineb dust check were inoculated at the indicated times by atomizing the trays with 5000 Verticillium malthousei spores/cc water.

c The zineb dusted check was grown in a small room separate from the other treatments, dusted three times per week with 15% zineb and was not inoculated with Verticillium. Zineb = (zinc ethylenebisdithiocarbamate).

APPENDIX II

FIFRA SECTION 18

SPECIFIC EXEMPTION FROM
EPA PESTICIDE REGULATIONS

State: Pennsylvania
Crop: Mushroom

June 21, 1989

Section I. Contact People

Applicant:

State: Dr. Gerald J. Florentine
Pennsylvania Department of Agriculture
2301 N. Cameron Street
Harrisburg, PA 17110
Ph: 717-787-4843

Experts: Dr. Paul J. Wuest
211 Buckhout Laboratory
The Pennsylvania State University
University Park, PA 16802
Ph. 814-865-1847
FAX: 814-965-3055
Telex: 902990

Dr. Mark Wach
Monterey Mushrooms, Inc.
P.O. Box 189
Watsonville, CA 95077
Ph: 408-728-8321

Section 1. Description of Pesticide

Name	Bravo 500
A.I.	Chlorothalonil, 4.17 lbs per gal. EPA Reg No. 50534-8
Mfg.	Fermenta Plant Protection Company Painesville, OH

Additional labeling proposed:

Note to user: Wear long sleeve shirt, long pants and gloves while mixing, loading and applying this product.

Bravo 500 has been found to be effective in the control of Verticillium disease on mushrooms in the United States and is registered for the control of those diseases on mushrooms in Great Britain and the Netherlands. Bravo 500 is a broad spectrum protectant fungicide containing 500 grams active chlorothalonil/liter (4.17 pounds active chlorothalonil/US gallon). Bravo 500 is currently registered in Pennsylvania to control diseases of potatoes, tomatoes, cole crops, and cucurbits. Bravo 500 has been granted Sec. 18 usage in the State of California and Tennessee for use on mushrooms.

Section 3. Description of proposed use

1. <u>Site to be treated</u>
   Bravo 500 will be used by mushroom farmers in the following Pennsylvania counties: Armstrong, Beaver, Berks, Butler, Chester, Mercer and Westmoreland

2. <u>Method of application - drench</u>

3. <u>Rate of application</u>

   Based on research results from California, Oregon and Pennsylvania, Verticillium diseases are effectively controlled with applications of Bravo 500 at 4.0 pints per 8,000 square feet made at casing, followed by 2.0 pints per 8,000 square feet made at pinning and 2.0 pints per 8,000 square feet made between each break for as long as disease pressure persists.

   Based on residue analysis, Bravo 500 applications should not be made to mushrooms within 36 hours of harvest.

4. <u>Quantity of Pesticide Use Expected</u>

   During the 1987-88 cropping season, there were 60.5 million square feet of mushrooms (7,563 units of 8,000 sq ft.). Each unit produces an average of 4.2 crops/year. It is estimated that Bravo 500 would be used on 80% of all crops for a total of 25,413 units. Based on the proposed use pattern, calculations can be made as follows:

25,412 units x 4.0 pts at casing	=	101,648 pints
25,412 units x 2.0 pts at pinning	=	50,826 pints
25,412 units x 2.0 pts/break x 4 breaks	=	203,304 pints
	Total	355,778 pints

It is estimated that 44,472 gallons of Bravo 500 will be used during the 1989-90 cropping season.

5. <u>Applicable restrictions other than those on label</u> - none, other than as noted in Section 2.

6. <u>Alternate Methods of Control</u>

   A. Cultural
   Sterilization of compost and casing materials prior to each production cycle, filtration devises on ventilating equipment, sanitization of rooms between cropping cycles and insect control have not proven sufficient to prevent spores of <u>Verticillium fungicola</u> from reaching and entering mushroom growing rooms.

B. Resistant Cultivars

There is no genetic resistance available in mushroom strains to control Verticillium brown spot and dry bubble.

C. Chemical

Only two groups of fungicides are registered for control of Verticillium dry bubble and brown spot on mushrooms. They include zinc ethylenebisdithiocarbamate, Dithane Z-78 (Zineb) and the benzimidazoles (Benlate and Mertect 340F)1.

Disease resistance to the benzimidazoles has hampered their effectiveness as disease-control agents. Benzimidazole resistant strains of Verticillium were identified in all areas of Pennsylvania by 1980. As a result, the use of benzimidazoles on mushrooms in Pennsylvania is no longer considered an effective agent for disease control.

Zineb has been the industrial standard in controlling Verticillium diseases on mushrooms since 1950, but zineb can no longer be imported into the U.S. There are no domestic manufacturers of zineb. Zineb is no longer available to mushroom farmers.

A third group of chemicals, tetrachloroisophthalonitrile (BRAVO W-75 and BRAVO 500) has been found to be effective in controlling Verticillium diseases on mushrooms. Bravo is effective with benzimidazole-sensitive and benzimidazole-tolerant strains of Verticillium.

In January, 1985, Rohm and Haas, a basic manufacturer of Zineb announced to the mushroom industry that it would no longer continue to produce Zineb. Rohm and Haas indicated that there would be sufficient supplies of Zineb on hand through the 1985 season. By mid-1985, Zineb was difficult to locate and by January of 1986, Rohm and Haas announced that all their supplies of Zineb in stock had been exhausted. FMC, the alternate supplier of Zineb from Europe, were informed that EPA was restricting importation of Zineb into the United States. Microflo Company, Lakeland, FL 33802, exercised its import license until a data call-in for Zineb resulted in the license being suspended by the Department of Commerce. Zineb in channels of distribution are gone, and zineb is no longer available.

7. Effectiveness of Proposed Use

The fungal pathogen, Verticillium fungicola, causes brown spot, stipe blast and dry bubble. The disease is found on several genera of mushrooms, including the common cultivated variety, Agaricus bisporus, the Oyster mushroom (Pleurotus ostreatus), and the natural, wild type, wood rotting fungus (Coltricha perennis). Spores of Verticillium are disseminated by wind, free-moving water, with flies, clothing, and cultural equipment.

Airborne spores of Verticillium are believed to enter mushroom growing rooms when fresh air is used to lower the carbon dioxide concentration and compost temperature prior to crop production. Flies and other insects may carry spores from infected mushrooms in other growing rooms. Further, Verticillium spores from mushrooms in nearby woods may enter growing rooms on clothing, air, or insects. Clothing and equipment contaminated with V. fungicola can introduce the disease from growing room to growing room, and splashing water from irrigation and misting can move spores from an infested area to a noninfested area.

Spores landing on peat moss "casing" soil germinate and infect the developing crop of mushrooms. They may infect the crop primordia reducing the number of cultivated mushrooms ("dry bubble" or stipe blowout) or infect the growing mushrooms to cause brown spots, reducing quality ("spot").

Under optimum cultural conditions and pest management practices, a grower will normally make 3 to 5 harvests (breaks) from a single planting of spawn. Verticillium can reduce the number of harvests to two or three. Under severe conditions, Verticillium disease can reduce the number of harvests to one. Yield losses of 40% are not uncommon with heavy disease pressure, and quality reductions of up to 50% occur (Gandy, 1981).

Mushroom growing facilities may contain many growing rooms,each having approximately 8,000 square feet of bed space producing surface. Since a single growing cycle for one crop requires 13 weeks, adjacent growing rooms each have continuous supply of harvestable mushrooms. Workers moving from room to room, for reasons of watering or harvesting, continuously transmit spores on clothing and equipment from infested beds to uninfested beds.

8. Residues For Food Use

An application from IR-4 for establishment of a tolerance provides EPA accession numbers that will provide residue information.

9. Risk Information

This has been assessed through the data call-in procedure, and EPA has approved the continued usage of chlorothalonil.

10. Coordination with Other State and Federal Agencies

The proposed use is not expected to be of concern to other federal or state agencies.

11. Miscellaneous

a. Copies of Section 18 approvals for this specific exemption for California and Tennessee.

Events Which Brought the Need for a Specific Exemption

Zineb was the mainstay for Verticillium brown spot and dry bubble control for decades. The data call-in for zineb resulted in Rohm and Haas announcing their disinterest in providing documentation, so they ceased manufacturing zineb. FMC chose to follow the lead of Rohm and Haas, and stopped importing zineb. The exclusive importer, Microflo Company, Lakeland, FL, had its import license suspended by the Department of Commerce, and now the zineb in the channels of distribution is gone. Zineb is no longer available and a/o 16 June 89, it cannot be used until the data call-in has been satisfied.

Anticipated Risks to Endangered Species

None

Anticipated Significant Economic Loss

Pennsylvania mushroom farmers received $205.1 million at their farm gates in 1988 for 284.8 million pounds of mushrooms (Exhibit 8). The nation purchased 631.2 million pounds from mushroom farmers in 1988 and Pennsylvania grew 45% of this total. Mushroom harvesting is not a single phenomenon at mushroom farms, but occurs in flushes (blooms or breaks), at weekly intervals. A farmer would expect an average harvest of 4.63 lbs/ft^2 in 5 flushes in which production is weighted into the earlier flushes. A farmer would thus expect to harvest 2.0 lbs on 1st flush, 1.93 lbs on second flush, and 0.7 lbs for the remaining flushes. The economic import of Verticillium disease is illustrated by realizing that spotted mushrooms do not qualify for fresh market grade and a heavily spotted mushroom cannot be sold as a processing grade mushroom. Spotted mushrooms result in a reduced price to the farmers or no market for badly spotted mushrooms.

Wuest, 1983, reported the cost of mushroom production as between $2.04 and $3.64/ft^2. Adjusted for inflation at 5% per year, the cost of producing and harvesting mushrooms in 1989 in $2.65 to $4.56 per ft^2. Thus, farmers have to produce between 3.31 and 5.70 lbs per ft^2 to maintain his/her business. The average production in Pennsylvania was 4.63 lbs per ft^2 in 1988. Verticillium disease causes crop reductions of nonsalable products in the vicinity of 10% at mushroom farms in Pennsylvania (Spadafora et al., 1986), which meant farmers without Verticillium should have averaged 5.09 lbs/ft^2 rather than the 4.63 lbs they reported in 1988. Considering that the production needed for survival of the farm business averaged 4.51 lbs/ft2 (3.31 to 5.70 lbs/ft^2) in 1988, the presence and persistence of Verticillium focuses sustainable losses with this disease without allowing for other causes of crop reduction. Mushroom farming has a variety of causes for crop loss and assigning much of sustainable loss to one disease enhances the financial risks associated with farming this crop beyond practicality.

The line between profitable and unprofitable mushroom farming is narrow measured by the 50% of mushroom farmers who left the business between 1980 and 1987 in southeastern Pennsylvania (Baillie, 1987). Bravo can reduce Verticillium disease by as much as 60%, and this benefits farmers by reducing the risks associated with growing this crop while increasing the volume of unblemished mushrooms available to consumers.

(References available from P.J. Wuest, 211 Wuest Laboratory, University Park, PA 16802.)

APPENDIX III

What Might Have Been in Fungicide Control of Verticillium[a]

The control of Verticillium has been and continues to be a controversial topic. In this article, two potential fungicides for this use are discussed as industry and the EPA attempt to achieve their respective needs.

PROCHLORAZ (Sporgon)

This fungicide has been used worldwide in the mushroom industry, with the exception of North America, since in the early 1980's. Use of Prochloraz has relegated Verticillium diseases to a position akin to sciarid fly control in the U.S. - controllable, provided the situation is monitored and the results of monitoring are acted on. Prochloraz was evaluated at Longwood Biological Laboratories by Dr. Fordyce and at Penn State by Dr. Wuest. Both found this fungicide to be effective for Verticillium control, although the level of control was not as high as others have indicated.

NorAm Chemical Co. of Wilmington, DE is the North American representative for this chemical, originally developed in England by another company. Representatives from the parent company in Germany came to Penn State to discuss the possibility for U.S. registration and were advised that EPA first had to decide if Prochloraz was safe to use at the dosages needed for disease control. NorAm submitted a petition to EPA requesting that Prochloraz be evaluated for its use on edible foods. The company had data on all aspects of this fungicide - those dealing with human health, safety and the environment - and were therefore able to satisfy the application procedure. Three years passed while EPA considered this request.

In the summer of 1988, EPA responded to NorAm that EPA toxicologists considered the active ingredient to be a probable carcinogen. Based on the litigious nature of the U.S. in general and the mushroom industry in particular, NorAm made a business decision in 1989 to withdraw consideration of Prochloraz for mushroom use in the U.S. The likelihood of NorAm changing its mind is minimal, so Prochloraz (Sporgon) will never be registered for use here.

DITHANE M-45 (Mancozeb)

In 1985, Rohm & Haas decided to stop manufacturing Zineb and to consolidate its fungicide registrations of Mancozeb, a widely used and effective dithiocarbamate (EBDC) fungicide for control of foliar blights, fruit rots and so forth. EPA initiated a Special Review of all EBDC fungicides on July 17, 1987 which was triggered by oncogenic risks (tumor, cancer) from dietary exposure and teratogenic (genetic) risks and thyroid toxicity to mixer/loader/applicators. Mancozeb has been identified as one of 53 potentially oncogenic pesticides by EPA and as a dietary risk by the National Academy of Science.

[a] Wuest, P.J., 1990. New options of Verticillium control. Mushroom News 38(4): 6,8,10-12. Reprinted with permission.

EPA position document 2/3 on EBDC fungicides published in the Federal Register on December 20, 1989 proposes the withdrawal of most Mancozeb registrations despite the voluntary withdrawal of many uses by the manufacturers of EBDCs before the EPA announcement. Public comments are being received by EPA after which EPA will publish its position on these EBDC fungicides.

What and how does this impact on mushrooms? Recognizing the need for an alternative for Zineb, research was undertaken at The Penn State Mushroom Center (MRC) to locate a substitute in 1985. One promising candidate was Dithane M-45. By 1987, enough information about Dithane M-45 on mushrooms had been developed to allow for the growing of a crop to provide mushrooms for residue analyses. Crops at three other sites in Pennsylvania were also arranged - at Sylvan Spawn, MGA (Kennett Square) and Longwood Biological Laboratories. Table 1 illustrates the disease control efficiency of Dithane M-45 at the crop grown at the MRC. These data indicate that Dithane M-45 is an excellent fungicide for controlling Verticillium

THE FUTURE FOR DITHANE M-45 ON MUSHROOMS

EPA will publish its final decision on the EBDC's some months after the public comment period ends. Their proposed position suggests that EBDC usage will be curtailed significantly and use of EBDCs on many crops will be cancelled. If this is how the world of the regulators comes down on this group of fungicides, there seems to be no chance of an additional registration being approved. The manufacturers of EBDC fungicides and the USDA have taken major exception to the EPA position as have hugh numbers of farmers and farm groups who will be significantly impacted by the restriction of EBDC usage. Whether Dithane M-45 can be registered on mushrooms will be measured in a time frame of years, so look for other ways to manage Verticillium disease.

Table 1. Influence of Dithane M-45 on yield and Verticillium disease control when applied to a hybrid white mushroom strain

Treatment	Breaks					Total
	Yield-lbs per sq. ft.					
Inoculated	0.87	0.70	0.22	0.02	0.02	1.86#b
M-45	1.14	0.73	0.36	0.20	0.32	2.76a
Uninoculated	1.08	0.73	0.47	0.23	0.36	2.87a
	Verticillium Brown Spot (%)					
Inoculated	42.2	12.0	54.9	63.5	79.8	48.4
M-45	17.9	8.4	8.8	18.1	34.8	14.7
	Dry Bubbles per sq. ft.					
Inoculated	0	0.5	12.7	37.7	56.6	107.5
M-45	0	0.1	3.0	5.6	4.4	13.0

APPENDIX IV

XII. FUNGICIDE RESISTANCE IN MUSHROOM PRODUCTION

Paul J. Wuest
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The Pennsylvania State University
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Introduction

This specialty crop is grown in 28 states, and during crop year 87/88, was worth $544.2 million at farm doors across the United States. In Pennsylvania, the mushroom crop is valued at more than the combined value of potatoes, fruits, and vegetables ($194.5 million vs. $134 million, 86/87). Importation of processed mushrooms from Pacific-rim countries during the past 20 years has resulted in US mushroom growers redirecting their production to fresh market outlets (25% in 1971/2 vs. 65% in 1987/8). This market shift has required development and adoption of new growing techniques and germplasm. Dependence on the fresh market requires that mushroom farmers grow, package, and deliver appealing, blemish-free mushrooms to retailers, restaurants, and institutional buyers.

Major diseases

I. Verticillium brown spot (*Verticillium fungicola*) is the most frequently encountered disease at mushroom farms, and its occurrence constitutes a serious problem on mushrooms being grown for the fresh market. The disease tends to be endemic, irrespective of the time of the year. A 1980 survey of 35 mushroom crops reflected disease occurrence in every crop surveyed with an increasing incidence as the crop aged, from .01% on first break to 20+% by fourth break. A qualitative survey of disease occurrence in 1984 yielded data from 60% of Pennsylvania mushroom farms and listed brown spot as the most significant disease for each crop.

a. Chemical Control

Chemicals registered to control this disease include dithiocarbamate, zineb, and the benzimidazoles (benomyl and thiabendazole).

1) Resistance monitoring has consisted of bi-yearly resistance assessments (since 1978), using media amended with benomyl, thiabendazole, or both. Isolates of the pathogen are obtained from farms

across the US, with isolation and resistance assessments being made at Penn State.

b. Resistance Incidence

1) Benomyl has not been effective in inhibiting germination of conidia or vegetative growth of the fungus in 95% of the isolates tested. During the 1980's, there tended to be more isolates which grew at 50 ppm benomyl than there were in the late 1970's. This monitoring procedure was initiated in about 1973, when mushroom farmers throughout the US reported lack of disease control with benomyl.

2) Isolates of V. fungicola respond somewhat differently to thiabendazole, in that laboratory assessments result in data akin to that for benomyl, yet disease occurrence and increase are reduced by the chemical in controlled cropping experiments. Thiabendazole decreases the total number of Verticillium-spotted mushrooms by 15-35%. Farmers have not corroborated these data as they cannot perceive varying disease levels when Verticillium brown spot is less than completely controlled. Further complicating this situation is the belief by farmers that one of the wetting agents in the flowable thiabendazole formulation enhances the likelihood of bacterial blotch, another quality-reducing disease.

c. Resistance Management

There are no mushroom cultivars with resistance to Verticillium brown spot, so this option is not available. Modifications to cultural practices have been under investigation for five years, and some disease reduction may be possible with this approach. The need for sanitation and hygiene have only recently been emphasized, and their implementation at mushroom farms is still in the developmental stage. Another strategy, the routine use of zineb, while reserving benomyl for occasional use, has not resulted in the reemergence of benomyl-sensitive strains as the predominant phenotypes at mushroom farms.

1) The import license for zineb was suspended by Department of Commerce in 1988, so supplies of zineb in distribution lines are almost nonexistent.

2) Chlorothalonil was reregistered in summer, 1988, and although IR-4 has reactivated their request for a mushroom tolerance, neither the tolerance nor a label are available for this broad-spectrum fungicide on mushrooms. Reports from Europe, Oceanasia, and England indicate that

chlorothalonil has been minimally effective during its 10-12 years of usage at mushroom farms in these countries. Currently, CA and TN have Section 18 labels for the use of chlorothalonil on mushrooms.

d. Availability of research on fungicide resistance in *V. fungicola*

There are no current studies as there are few options in chemical disease control. Thus, resistance management, population shifts, and mechanisms of resistance are academic questions, with no potential of benefitting mushroom growers.

II. LaFrance (virus induced)

This disease is a significant crop-reducing disease, and management is aimed at sanitation, hygiene, and indexing. Use of zineb dust (15%) as a protectant has been effective in minimizing secondary infections by basidiospores from La France diseased mushrooms. There is no alternative to zineb, and resistance to zineb in *Agaricus bisporus* basidiospores has not been reported.

III. Mildew Diseases

The pathogens responsible for these diseases are *Trichoderma viride* and *Hypomyces roseullus* (*Dactylium dendroides*, imperfect stage). These diseases can be significant when they occur, but their occurrence is infrequent when compared with Verticillium brown spot. There are no research reports of resistance in either of these pathogens to benzimidazoles. Anecdotal information from farmers suggests that *H. roseullus* is resistant to benomyl; however, these reports have not been validated through research.